02C-4058

COPY 2 OF 2

Westinghouse Electric Corporation

Air Arm Division

Friendship International Airport
Box 746, Baltimore 3, Md.
Telephone: 761-1000

November 14, 1962

A38521S

Special Projects Office (ASZ-5)
Plans and Programs Office
Directorate of Production
Wright-Patterson Air Force Base, Ohio

SUBJECT: Monthly Progress Report
Contract AF 33(600)-40280
Westinghouse Ref. DYD-45196

Enclosure (1): Three (3) copies Monthly Progress Report for Period May 15, 1962 to June 15, 1962.

Gentlemen:

Enclosure (1) is submitted as required by the subject Contract. One copy of this report is also being sent to [redacted]. STAT STAT

Very truly yours,

WESTINGHOUSE ELECTRIC CORPORATION

[redacted] STAT
Project Liaison
Marketing Department

RWE:sf

cc: [redacted] STAT

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Encl #1
DXC-4058
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PROGRESS REPORT
May 15, 1962 to June 15, 1962
Contract No. AF33(600)-40280

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APPENDIX

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A. General

System flights were made during three days of the twenty-five working days in this reporting period. Reasons for failure to fly during the remaining twenty-two days can be broken down as follows:

APQ-93 System down	10 days
F-101B Aircraft down	6 days
Weather bad	6 days

During the three flying days, a total of five system flights were made, flights S-13 and S-14 on May 31, S-15 on June 1, and S-16 and S-17 on June 15.

Flight S-13 failed to produce any useful data because of an RF failure. No output pulse or video could be seen on the oscilloscope in the cockpit.

A CRT failure occurred just after take-off on flight S-14. Two runs were completed before weather conditions caused the flight to be ended. Post-flight investigation indicated that the CRT failure was caused by a defective pot in the CRT sweep voltage circuitry. The pot was replaced.

Flight S-15 produced no useful data because of continuing erratic operation of the CRT sweep voltage. The circuit was found to be heat sensitive and modifications were made to the recorder to provide external cooling.

Flights S-16 and S-17 were made on the last day of the reporting period and analysis of the data indicated that ample video was recorded on the film.

Appendix 1 contains a summary and analysis of the film data for the above flights.

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The six days of "aircraft down" time during the month were caused by two maintenance items. One was an Air Force grounding technical order requiring check and rework of the F-101B landing gear. The other was a defective fuel boost pump which required replacement. This replacement was complicated by having to remove the APQ-93 antenna and its pylon to gain access to the pump.

B. APQ-93 System

Average transmitted power was increased from approximately two watts at the beginning of this reporting period to approximately 8 watts at the end. This improvement was due largely to replacement of components. A new Duplexer, new Duplexer switches and a new "tail bite" switch on the modulator output were incorporated.

Failure to transmit an adequate pulse was the cause of only two days of "system down" time during the month.

The primary cause of system trouble was the APQ-93 Recorder.

Erratic CRT sweep voltage was the cause of system failure during flights S-14 and S-15. Between June 1 and June 7, the recorder was returned to ITEK for installation of a new CRT. The modified recorder sweep voltage circuit was found to be heat sensitive and modification was performed to provide for external cooling. This modification has apparently corrected the overheating problem.

The CRT light level has proved to be unstable. Drifting of the light level has caused CRT failures during system flights. This problem has been temporarily remedied by locating the light level pot in the cockpit.

The pot is adjusted by the radar operator to compensate for the drifting level. This configuration worked successfully during flights S-16 and S-17, but it is undesirable and does not solve the basic problem.

Doppler Frequency Tracker tests have been conducted using the aircraft system on a non-interference basis. More development is required on these units.

A meter has been installed in the cockpit to give the radar observer drift angle information for manual offset compensation. The circuit has not as yet been aligned and calibrated.

The Buffer Monitor circuitry has been installed and checked out. The monitor will indicate an RF failure in "Standby" if the Buffer amp output is low.

A second TWT was installed in series with the present tube in order to increase the overall gain into the Recorder. It was found, however, incorporation of the second TWT raised the noise figure above tolerable limits. The additional TWT has been removed from the circuit.

C. Instrumentation

Summary

To provide recording facilities for higher frequency signals, an Ampex AR-200 magnetic tape recorder has been installed in the F-101B aircraft.

The tape recorder has 7 direct record channels, four of which are now in operation and three of which are spares.

The Antenna Beam Accelerometer and the Frequency Tracker potentiometer position circuits (refer to previous Monthly Progress Report, April 15 to May 15) are in operation. The film marker and the Doppler tracker error signal circuits do not have any inputs as yet from the APQ-93 system since the input circuits are being modified.

Modification

A new Doppler Video signal, with a frequency range from DC to 600 cps, has been added for recording. Since the CEC oscillograph recorder in the F-101B aircraft provides only a few minutes of recording time at this high frequency (due to the high speed of the paper), it has become necessary to use a second recorder, i.e. a magnetic tape recorder with FM channels. The FM channels of the available Ampex AR-200 magnetic tape recorder records at a tape speed of 60 ips. This affords only 12 minutes of recording time, i.e. less than 40 percent of the required flight test time. To expand the recording time to 48 minutes, 3 FM plug-in units (15 ips) have been ordered for the recorder FM channels. To avoid any delay, the 500 cps signal will be "direct" recorded. This method of recording and reproducing enables the recording of signals from 58 cps up to 35K cps (-3 db points). In addition to the above channel, two direct channels are used for data correlation and one is used for the operator's and the pilot's comments. The remaining 3 channels are spares.

Present Status of Instrumentation

The Ampex AR-200 tape recorder with a 7 channel electronic unit has been installed in the aircraft. To operate the tape recorder from the cockpit, the programmer, data correlation, and the remote control units have been modified by adding new components and wiring. The cable interconnections have been completed and the tape recorder is ready for operation. (A small converter might be necessary for recording the narrow data correlation pulses. The VCO voltage controlled oscillator is available to do this).

Oscillograph Data

Appendix 2 contains a summary and analysis of the oscillograph data.

D. Antenna

Antenna No. 1 (conversion of Flight Test Antenna to end use configuration).

Fabrication

Manifolds - 2 additional manifolds required - complete

Array Sticks - 32 additional array sticks required - complete

Modules - 2 additional modules consisting of above parts are assembled but not soldered or grown together.

Honeycomb Beam - complete

Power Dividers - complete

All Hardware - complete

Assembly and Test

Reconversion of Antenna No. 1 will start at the completion of the Flight Test Program (scheduled for completion on 15 July 1962).

Antenna No. 2

Fabrication - complete

Assembly - complete

Test - A temporary test range has been completed and testing started. Results so far indicate that a phasing problem exists and that range reflections are causing a non-uniform illumination of the antenna. Phase measurements have been made on the manifold and the results indicate that a phase error exists between the first and second chamber of each manifold. Extensive effort will be continued until the major causes of loss of gain and high side lobes are identified and the correction known.

Antenna No. 3

Fabrication

Manifolds - complete

Array Sticks - complete

Modules - 7 of the 8 required modules have been assembled, tested and grown together. All seven modules have excessive leakage. A program to seal these modules has been underway with the assistance of the Components Section. A lead-indium solder has been found that should be a satisfactory solution to the leakage problem. A soldered sample has been subjected to repeated cycles of pressure and temperature for over 150 hours without leakage. A second sample, coated with silicon rubber has been tested as above for over 60 hours without leakage.

The eighth module has been assembled and is being used as a test sample in the investigation of R.F. problems on Antenna No. 2.

Honeycomb Beam - complete

Power Dividers - complete

Other Parts and Hardware - complete

Assembly and Test

Held up pending investigation of RF problems on Antenna No. 2.

E. Switch Tubes

Two WX-4641 tubes, numbers 6 and 7, were delivered. Further units are being fabricated. Completion is being delayed only to evaluate a new electrode design which it is believed will reduce arc jitter. This design will be put into the last four tubes.

For evaluating the WX-4554 tubes, the ring circuit was assembled and thoroughly checked and calibrated. Using a fixed short at the tube location, the maximum power obtainable was 400 KW peak at a prf of 3500 cps. Replacing the short with a WX-4554 tube dropped the power in the ring to 180 KW. A tube is presently being evaluated at this power level. Comparison of tube performance for the same incident power per window when in the ring and when at the end of the transmission line will be made. This will determine whether it will be permissible to test at a power level of 100 KW without a ring circuit. If so, it would save much time in optimizing ring performance.

At present, two WX-4554 tubes are being assembled. These tubes are to be high temperature brazed and silver plated in an effort to reduce low level loss.

F. Modulator

The three modulators are operating with the KPA's at their recommended mode voltages and currents.

An EG&G thyration was tried as an improved replacement for the present one, and found to exibit about the same characteristics as the KU72 in this application. No progress has been made in reducing the inverse voltage on the thyratron anode although seve al approaches have been tried including a hydrogen diode in place of the silicone diode now used. The power supply was changed from 6.7KV nominal at 120 ma to 5.8KV at 140 ma to accomodate the lower impedance (100) network.

Modulator SN002 was brought up to date with the 100 network and the addition of the inverse circuit for use in the system in RI tests.

G. Synchronizer

No change in status.

H. Frequency Generator

No change in status.

I. Frequency Changer

A breadboard has been built and tested.

J. Recorder

General

Recorder No. 3 was completed and delivered during this reporting period.

Resolution measurements on this recorder from the cathode-ray tube, fiber optics and film, indicated an equivalent spot size of 1.2 mils for the system. This corresponds to a recording capacity of approximately 400 cycles per second per inch in the azimuth direction.

Sensitometric tests of films for the lens recorder indicate that the Tri-X negative and Photoflure (blue sensitive) film stocks will be suitable. The Tri-X film is a low gamma film, while the Photoflure is a high gamma film. Both films will be tested when the recorder is complete.

Mechanical

Mechanical assembly of the Optical Recorder was completed at the end of May. Covers were received and their installation is complete.

Work was completed on converting No. 2 recorder from a Westinghouse to a G.E. tube. On completion of electrical testing of the G.E. tube, it will be a matter of less than an hour to interchange tubes.

Design of a device to wind the watch from the side is nearing completion and a shorter stem watch has been ordered.

Optical

Both lenses were installed in the recorder, and the main optical system was aligned and focused. A slab of BK-7 optical glass was ground and polished flat to an accuraly of less than 0.001" and was 0.492" thick. The glass was used as a CRT faceplate simulator, and two lines 1/4" apart, plus a centerline, were scribed on the glass to represent the two traces. The simulator was mounted on the tube plate which in turn was mounted and aligned with the main reference plate in the recorder.

The centerline on the simulator was aligned with the roof of the reflecting prism to insure parallelism of the traces with the prism. The images of the trace lines were projected through the slit of the light baffle to the capstan. The rear mirrors were adjusted to remove tilt from the images, so that the two images appeared in a straight line, end to end along the capstan.

Resolution targets were placed over the scribed lines and by observing the images through the microscope, the optics were focused. The visual image quality appeared to be quite good, although final alignment was not completed.

Test Equipment

The resolution test set is under construction and should be completed in the early part of June. A light which permits measurement of the light on the output end of the fiber unfolding array has been devised.

G.E. Cathode-Ray Tube

The General Electric Microspot tube has been undergoing an evaluation study. Some difficulty has been experienced with the unconventional power supply voltages required; the solution, it is felt, is to await the arrival of a special power supply, specifically designed for this tube before making a final determination of the operational value of the CRT. The major problem with the tube is the interaction of control voltages.

K. Navigation Tie-in

No effort has been expended on this unit during this report period.

L. Spares

There has been no change in the status of the spares during this period.

M. Instruction Book

The handbook has been released for reproduction.

N. Test Equipment

Design Evaluation Test Equipment

All of the Design Evaluation Test Equipment with the exception of the Pulsed R.F. Stability Tester and the Azimuth Resolution Optics Assembly has been delivered to the roof lab.

The equipment has been aligned and checked. The tests that have been performed indicate that the test equipment will fulfill its specified function.

Azimuth Resolution Optics Assembly

The changes to this assembly have been held to a minimum in order to make maximum use of the parts of the present assembly.

When evaluating the film for azimuth resolution only a portion of the fresnal zone will be used. If the complete zone were used it would be necessary to have special lenses ground. However, by using only a portion of the zone, lenses that are presently available can be employed. This is advantageous in both time and money. As long as the portion of the zone used is not extremely small no deterioration of the focus can be observed. Limiting the zone in this manner is advantageous in that the intensity of the background light is reduced considerably.

Although test film is not available, a strip of flight film containing some point targets has been made available for evaluation. Figure 1 and Figure 2 show the results of evaluation of a point target from this film. The plot on Figure 1 shows the system focus on the left and the target focus on the right. Figure 2 shows the same target but the system focus has been deleted by an optical stop. The gain of the system has also been increased.

Modification and assembly of the Azimuth Optics will be completed by 6/24. Alignment of the unit should be completed by the beginning of July.

Pulsed R. F. Stability Tester

Figure 3 shows the unit as originally proposed. Figure 4 shows the unit which will be delivered. The reasons for the changes are detailed below:

It was originally proposed that only deviations of one hundred cycles or more need be detected for observation. This has now been changed to deviations of two thirds of a cycle or more.

To accomodate this change the frequency dividers and the frequency multipliers shown in Figure 4 were added.

The offset frequency that will be used will be one thousand cycles. The test equipment uses the first one thousand cycle line. However, we have been informed that the video amplifier in the system cuts off at approximately eighty thousand cycles therefore the particular line which is of interest in this test will not be available at the output of the system video amplifier. The project was adverse to installing a test point which would make the output of the synchronous detector available for test purposes.

This made it necessary to fabricate a synchronous detector and to design and fabricate a video amplifier. The passband of this amplifier has to extend well below one thousand cycles.

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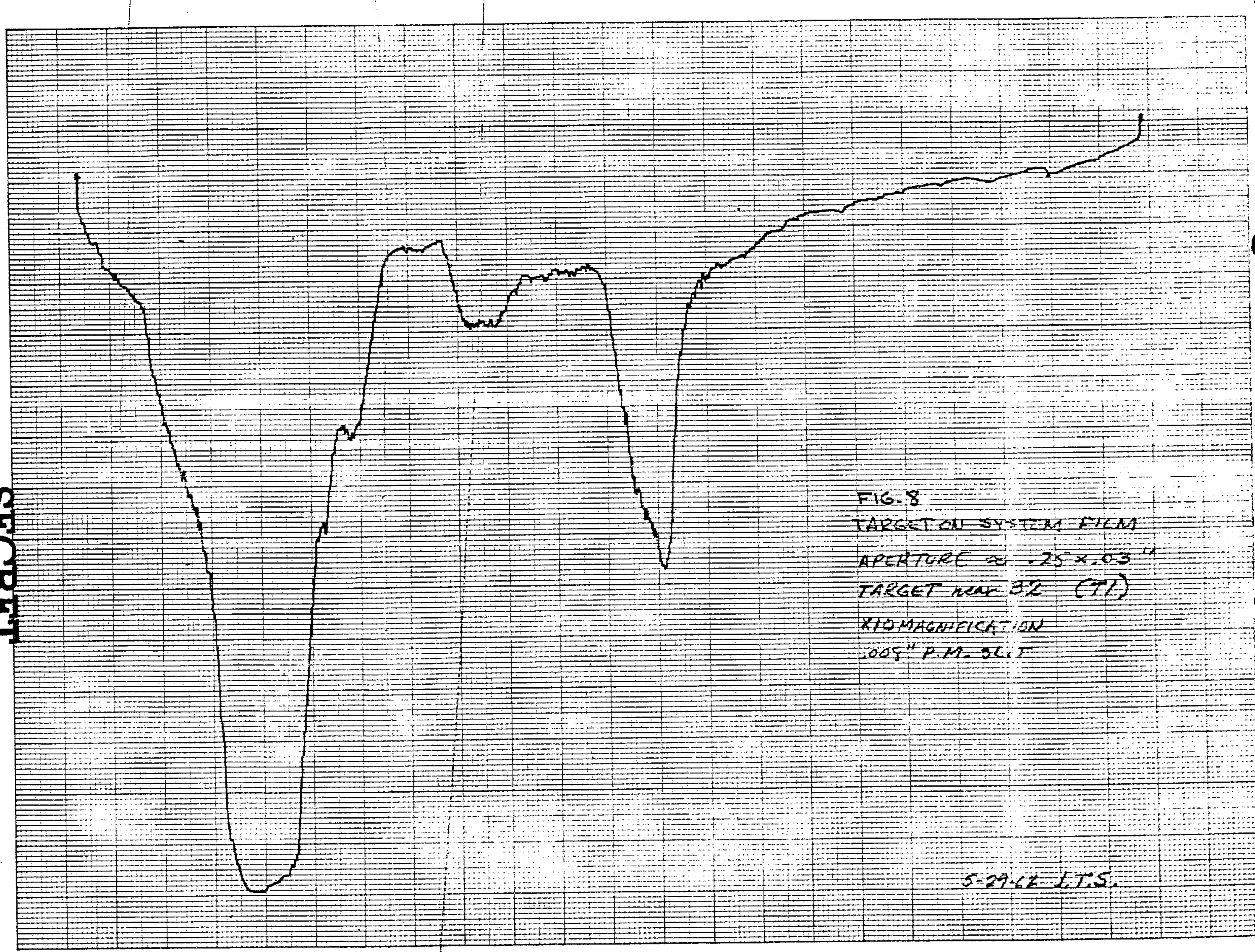

Figure 11

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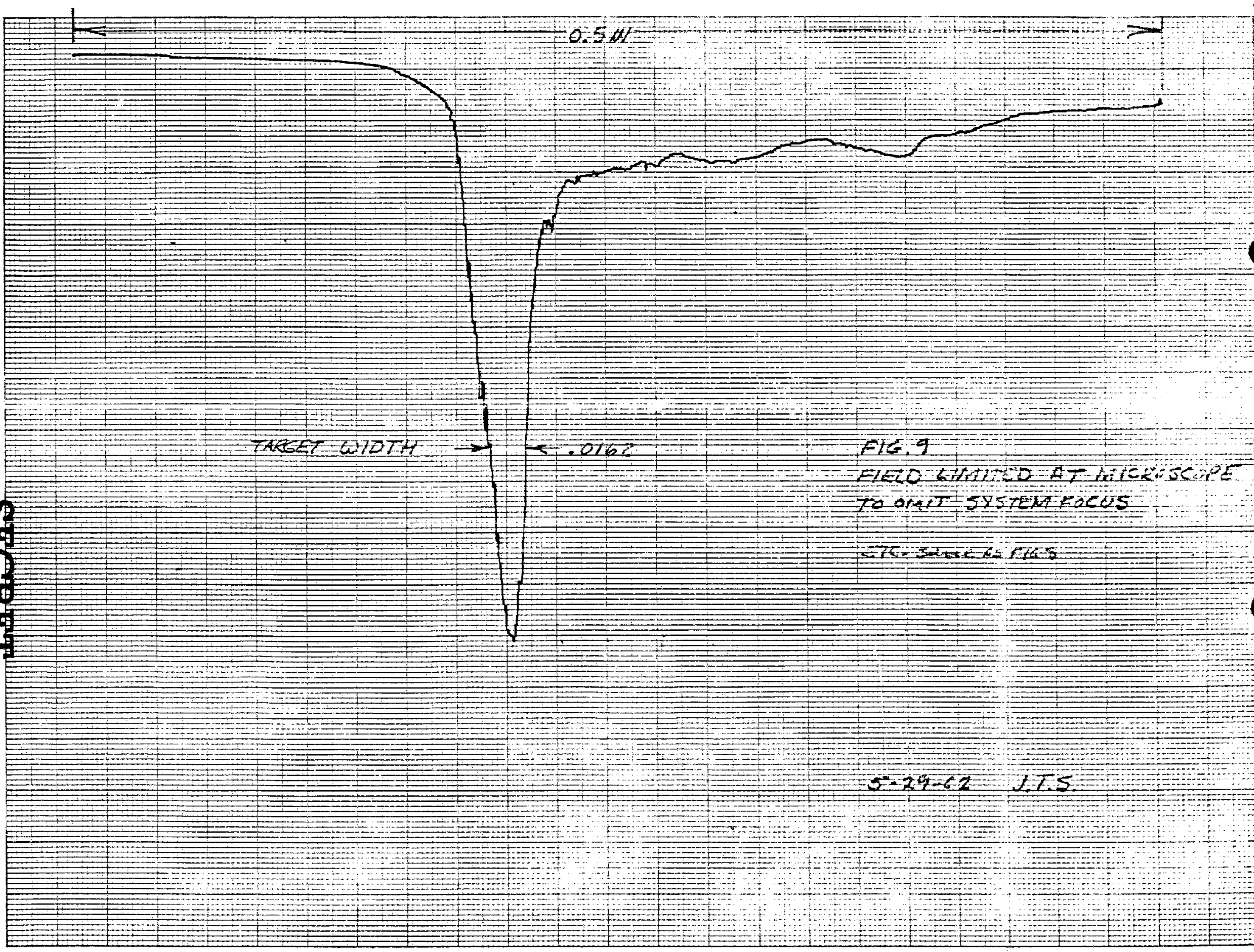

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Figure 12

SKETCH SHEET
WESTINGHOUSE FORM 2444 D

WESTINGHOUSE ELECTRIC CO[illegible]ORATION

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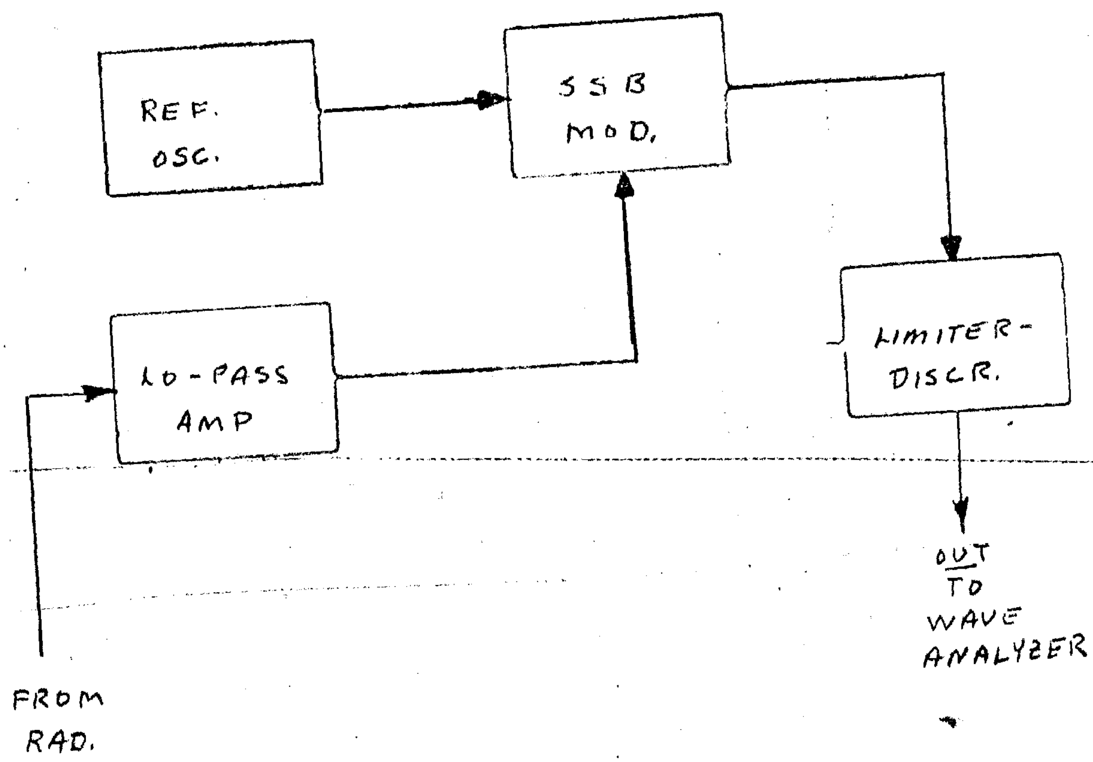

FIGure 3

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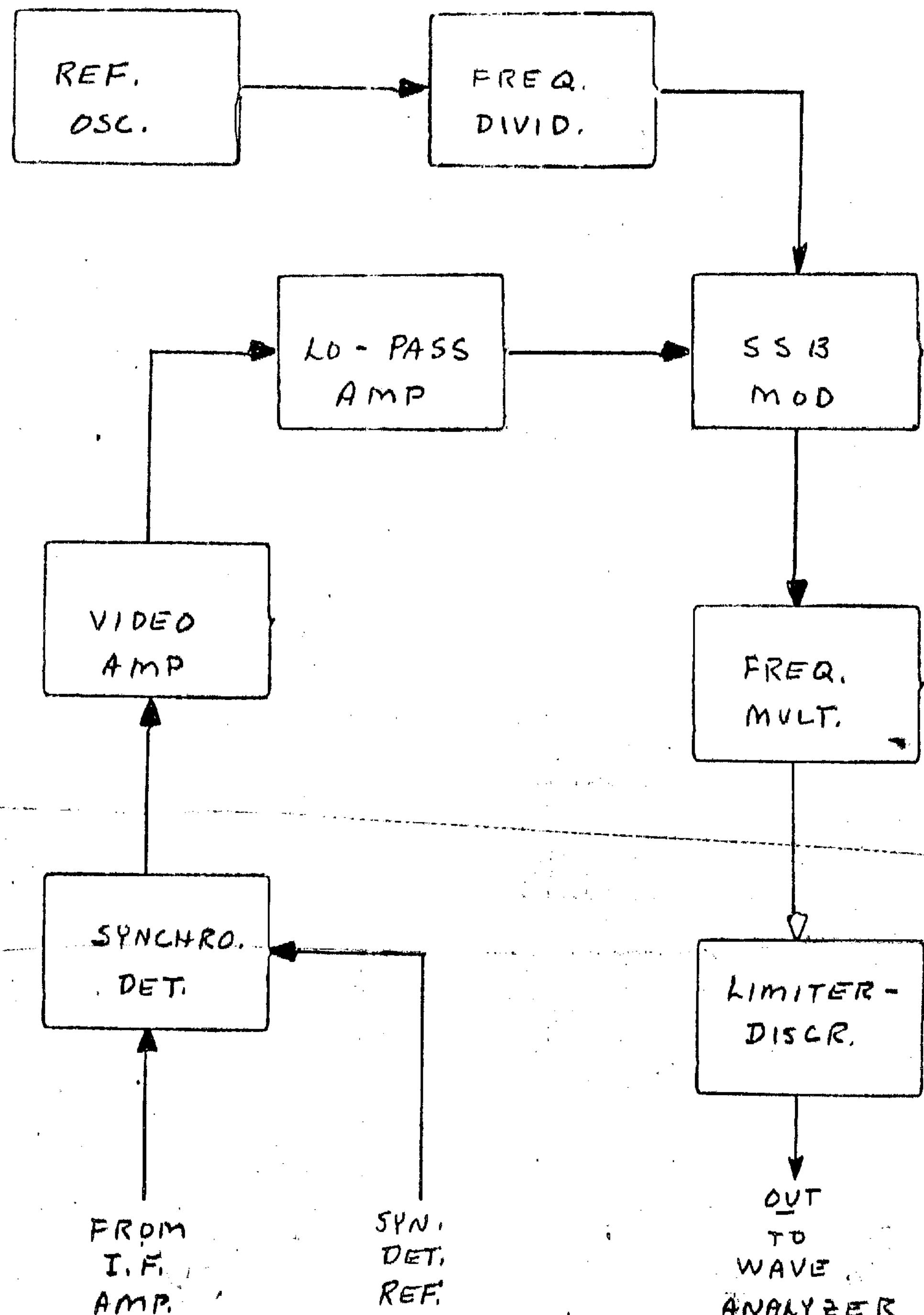

FIGure 4

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The unit has been built up and is presently being checked in the lab. It will be ready for installation in the test rack by the end of the month.

Field Test Equipment

All of the plug-in units have been released to drafting. Drawings for six of the plug-in units have been completed and the parts have been ordered in preparation for release to the model shop.

The initial release has been made to the model shop. Mechanical items such as plug-in cans, chassis, etc.

Transponder

A sketch of the transponder chassis has been released to drafting. The field unit of this chassis will be very similiar to the Evaluation Equipment unit except for the deletion of the clutter channel.

Range Resolution and Dynamic Range Test Pattern Generator

The PRF oscillator which has been redesigned and breadboarded is functioning satisfactorily. The redesigned oscillator can be tuned with a single control rather than with two controls as on the Evaluation Test Equipment. This will make it possible to calibrate the PRF setting. To obtain a precise indication of the PRF setting it will still be necessary to observe the frequency with a counter.

The stepping switch driver has also been reworked and is operating properly. This redesign insures that the ferrite attenuator will remain at minimum attenuation at all times other than when the Dynamic Range Test is being performed.

Range Delay Unit

The field equipment will operate with three discrete ranges rather than a continuously variable range. This will allow a great simplification of this unit.

A delay line with the appropriate drivers and switching will replace the digital delay circuitry which was used in the Evaluation Test Equipment.

This unit will be incorporated as a sub assembly of the Range Resolution and Dynamic Range Test Pattern Generator.

Delay line suppliers have been contacted but no firm commitments have been received.

Azimuth Resolution Test Pattern Generator

The multipliers and the modulators in the servo loop are being reworked for the Field Test Equipment. A demodulator, which will be added, is being designed.

The multipliers are being transistorized and will multiply by three instead of two. This will reduce the number of circuits necessary and will also simplify the input wave shaping necessary in order to obtain the desired harmonic.

The rework of the modulator and the addition of the demodulation constitute a refinement of the servo system for the field unit.

A breadboard of these subassemblies has been built in the lab and is being tested. Information on these subassemblies should be released to drafting by 6/24.

In order to insure compatibility between the Test Set and the prime equipment it was decided to increase the passband of the single sideband filters. Some difficulties obtaining a supplier who is capable of producing filters at 120 mcps was encountered. To date we have only found one supplier who indicated capabilities at this center frequency. Four other suppliers have indicated they could not produce the desired filter.

Control Panel

To date no effort has been expended on this unit.

Range Resolution Optics Assembly

Tests that have been performed with the Evaluation Test Equipment indicate that the upper optics assembly can be eliminated. This will be done in the Field Test Equipment.

A smaller motor and a simplified gear train for the prism drive will be incorporated into the Field Test Equipment. Sketches of these modifications will be released to drafting during the next reporting period.

Azimuth Resolution Optics Assembly

The optics for the Field Test Equipment will be identical to the Evaluation Test Equipment, however, the mechanical packaging will be changed slightly from the Evaluation Test Equipment. No effort has been expended on this unit to date.

Film Evaluator Electronic Circuitry

The Film Evaluator will differ from the present circuitry in the following respects only:

It will contain its own power supplies. Therefore, it will not require a connection to the main test rack. It will need primary power only--115V, 60 cps, 115V, 400 cps and 28 VDC.

A chassis containing zener diodes will develop the various voltages necessary using two basic power supplies.

In all other respects the unit will be the same as the Evaluation Test Equipment.

Mechanical Design and Packaging

Outside suppliers have been contacted to supply the rack and dolly as a single integral piece. They are at present working up a written quote which should be in our hands within the next week.

O. Doppler Frequency Tracker

The problem which developed during the previous reporting period was found to be a spurious signal arising from the various mixing products developed. A combination of three traps, at different frequencies and physical locations, reduced the spurious so that operation appears feasible.

During the past reporting period, while the troubleshooting continued, it was decided to initiate a parallel, back-up effort. Another technique was formulated, circuitry devised, breadboarded, and built into packaged form.

Warnings of low signal-to-noise ratios in the radar receiver prompted the use of a single-sidebanding scheme in the original DFT unit, tapping our input signal from the radar IF. Using the video following synchronous detection would have degraded SNR by 3 db. The resultant double-conversion technique generated the harmonics which have contributed to our problems.

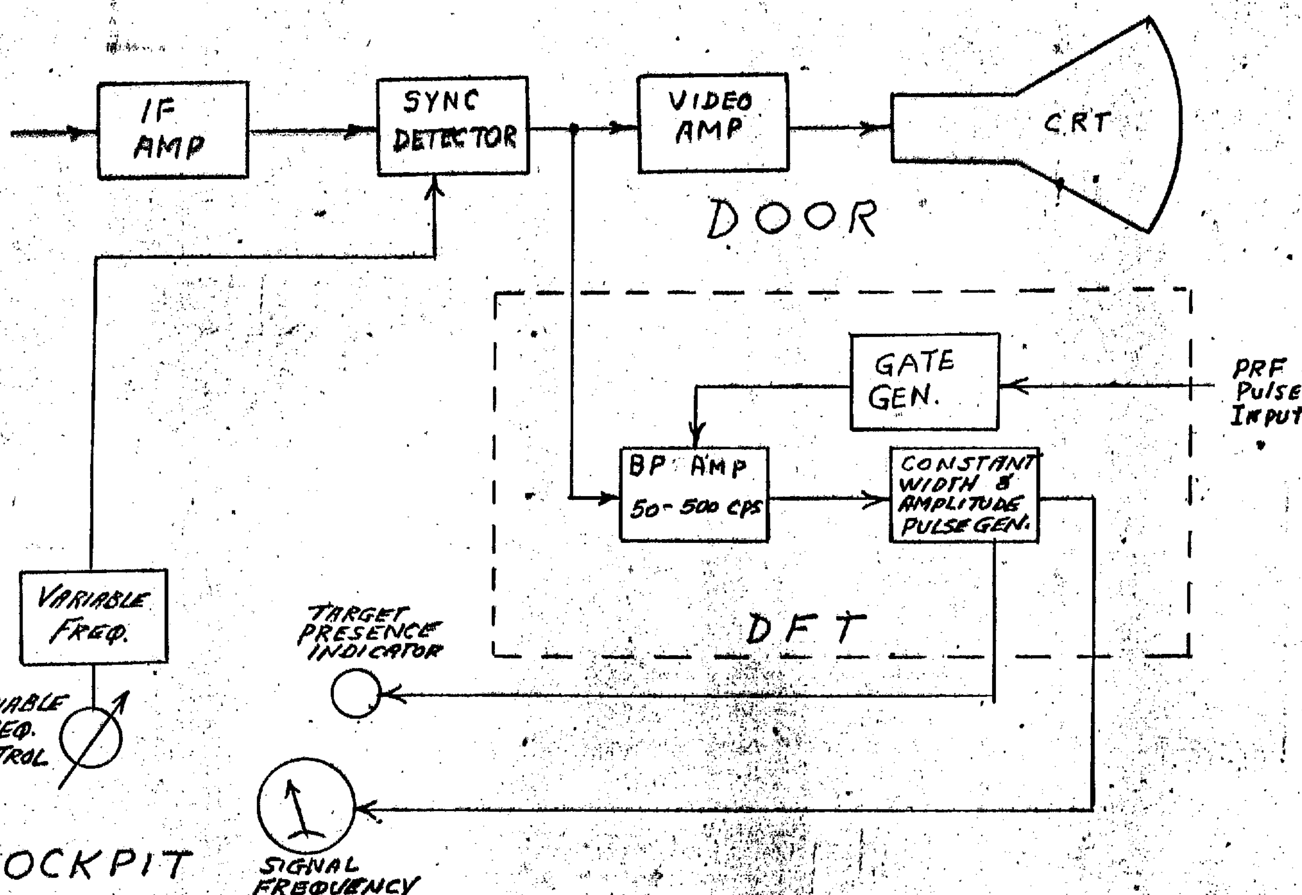
A later input has raised the anticipated SNR, making a 3-db degradation more tolerable, and opening the way to the use of the sync detector output. The remaining difficulty is the folding over of spectral lines due to the small offset frequency; they are so close together that the discriminator already developed couldn't be used. The alternative is to use the only line which is not one of a pair—the one which appears at the offset frequency, or, rather, at the actual offset frequency minus one PRF.

To do the above requires low-frequency techniques, the spectral line appearing nominally at 200 cps. Thus, a frequency counting method will be used after suitable amplification and range gating. Zero crossings of the signal will generate pulses of constant amplitude and width; the rectified output will thus be proportional to frequency, and may be read out on a meter.

The proposed circuitry has been breadboarded and tried out with a simulated signal input. It is now being built into a packaged, flyable form, after which electrical test will procede.

The circuitry, fully transistorized, will be mounted on component boards which, in turn, will be supported by and mounted by standoffs to aluminum plates. These combinations will be housed in a box which can be mounted in the flight-test radar, in the space allotted to the DFT unit.

A block diagram of this auxiliary DFT unit is shown below:



P. Design and Evaluation

There is some question as to the system frequency stability. Some tests indicate that there may be frequency modulation or other spurious frequencies being generated in the system. G.S.E. has completed a discriminator which with a sonic spectrum analyzer will be used to examine the receiver output for such frequencies if they exist. Furthermore, a new sonic analyzer whose spectral band extends to 0.5 cps is due to be shipped and would be used instead of the present 5 cps analyzer.

The resolution and dynamic range tests and the remainder of the evaluation program can be started as soon as a recorder is available. A calculated resolution budget has been made based on present component parameters. Under flight test conditions the resolutions in azimuth and range are 26 feet and 20 feet respectively. In the design system the azimuth and range resolutions are 13.5 feet and 35 feet respectively.

Q. Environmental Test

After roof lab tests on System #2 of the AN/APQ-93(XA-1) were concluded, the equipment was delivered to the screen booth lab for radiation interference test measurements. The system was delivered, less modulator and recorder; initial power checks were satisfactory. Tie-in to the simulated navigational equipment was made with a minimum of adjustments required. After the modulator was delivered, a full operational checkout indicated the system was ready (less recorder) for R-I tests to begin at the end of the reporting period.

APPENDIX

1. SUMMARY AND ANALYSIS OF FILM DATA

Five radar flight numbered S13 through S-17 were made between May 15 and June 15 in the Annapolis-Chesapeake Bay Bridge-Baltimore areas; all flight being made at an altitude of 20,000 feet with a ground speed of approximately 585 knots. Video was recorded on all flights except S-13 and S-14 which encountered system failures.

Flight S-15 consisted of four runs over Annapolis and the Bay Bridge areas and two runs over Baltimore with the radar being operated in both automatic off-set correction and manual off-set modes. A malfunction in the recorder electronic package prevented the acquisition of film data which could be correlated into a radar map. This malfunction caused a random transposition of range lines on the face of the CRT and also caused the range presentation to be shortened physically.

Radar run #1 of flight 15 was made with automatic off-set correction and runs numbered 2,3 and 4 were made with zero, (+)100 cps and (-) 100 cps manual offset correction respectively. The usual and desired "oatmeal" appearance or hologram type construction of targets was not present on any runs. Runs 5 and 6 were made over Baltimore with automatic offset correction. Very strong video due to buildings, piers, etc. was recorded on the film but ground return was weak. Only occasional hologram construction is apparent in automatic operation.

Indications are that an improper offset was used. The oscillator offset for this flight was 4480 cps, 50 cps higher than flight S-11. The near zero drift angle (approximately 0.25°R) encountered on this flight produces a true off-set of 4482-3930 = 552 cps. Run #2 of flight S-11, which produced low-high holograms, had a true offset of 564 cps. The difference between these two values of offset is 12 cps which indicates the lack of holograms may be due to unknown frequency shifts.

8 The radar operator reported that he observed external radar interference on his "A" scope during a portion of run #4, but no interference is apparent on the film.

Flights S-16 and S-17 were made on June 15. Again, automatic offset correction and various values of manual offset were used in an attempt to determine the proper offset value for flight.

The radiated power on these flights was higher than any other to date, and this increased power was evident on the film by good presentation of ground return and very strong video from bridges around Annapolis and from Baltimore City. However, little of this strong video was of value due to the absence of holograms. An oscillator offset of 4287 cps was used on these flights which produced a true offset of 4287-3930 = 357 cps. with an assumed drift angle of zero degrees. During manual operation, the RO inserted a correction of 1°R draft in flight 15-16 and a correction of 3°R in flight S-17 which increased the offset by 282 cps and 846 cps respectively. This is based on ground speed of 585 knots.

In manual offset correction, variations in actual drift angle and ground speed are not corrected. None of the runs in manual operation produced hologram type video which could be correlated into a radar map.

The last two runs of S-17 were made over Baltimore with automatic offset correction, and the last 30-40 seconds of each of these runs produced "oatmeal" and hologram construction. Plots of drift angle, ground speed and frequency correction command as taken from the instrumentation recorder do not point out any significant cause for this change of video pattern as the flight progressed.

Lack of hologram construction of video has been a problem since flight S-12. Since that time, the recorder, modulator and ring assembly has been changed, and the antenna was removed and reinstalled after the antenna pattern was measured. It remains to be determined if one of these factors could be contributing to the offset problem.

Fixes made in the recorder to correct the transposition of range lines that appeared on flight S-15 were successful. The only apparent recorder problem on flights S-16 and S-17 is the misfiring of the data flash and a transient which extends across the full width of the film. This transient is coincident with the time interval between data flashes and occurs even when the data flash misfires. The processing of the film produced poor readability of the data clock.

A zero beat frequency appears on portions of Runs 5 and 6 of flight S-17; the intensity modulation effect starting at near range and gradually decreasing as range increases. This zero beat does not reflect any change in the videod. This zero beat occurred only on these two runs when the offset frequency was 100 cps or less. However, CEC instrumentation records more instances when offset was less than 100 cps than when zero beat occurs on the film.

APPENDIX

2. OSCILLOGRAPH DATA - AIRCRAFT INSTRUMENTATION

Summary:

The main effort of the data analysis group was aimed at exploring the frequency correction command in flight. Numerous graphs were made of the measured frequency correction command f_c and the calculated value, f_{cc}. In short, a bias exists between them, and they do not follow one another very closely.

Temperatures are given in the report for most flights. Characteristics of aircraft and pod were normal

Flight 13 May 31, 1962

Since no film data was obtained due to a blown fuse, little C.E.C. analysis was done. All aircraft and pod characteristics were normal.

Flight 14 May 31, 1962

From the C.E.C. tape it was noted that the frequency correction command was oscillating. Each section of oscillation seemed to be triggered by a 28 volt pulse which was in turn caused by the CRT failure light blinking. Other temperatures, power supplies, aircraft characteristics and pod characteristics were normal.

Flight 15 June 1, 1962

A comparison of the f_c recorded and f_{cc} calculated was made.

$$*f_{cc} = f_o \pm .482\, V_{g} + 19.1\, V_B \qquad (1)$$

As before, the recorded values seemed to be biased 250 to 300 cps higher. Besides this bias, it was found that the frequency correction command kept jumping as in flight S-14. See figure 1.

* See page 32 for derivation

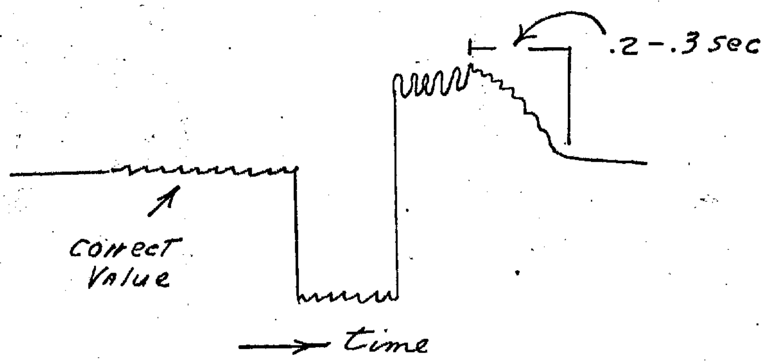


Figure 1

In flight S-14, the erratic operation seemed to be triggered by a pulse on the 28V DC bus. However, on flight S-15 this pulse was missing.

Many sources were checked to find this, but none were found faulty. However, many units were replaced and the fault has not occurred since. This jumping would have seriously degraded any data taken in automatic mode. The source of the bias error in f_c was investigated but could not be located definitely.

Power supplies were normal; aircraft and pod characteristics were normal. Temperatures are given below for this flight at 17,000 feet.

Temperatures*

Nose Compartment Air	41°F
Duplexer Driver Surface	94°F
Duplexer Surface	100°F
Duplexer Surface Switch End	83°F
High Voltage Power Supply Air	120°F
Pulse Network Surface	100°F

* Ambient Temperature = 0°F

Flight 16 June 15, 1962

Figure 3 to 7 are the calculated and measured frequency correction for each of the four runs. Run I in automatic showed very little bias level between f_{cc} and f_c. Here the measured value was slightly lower than the calculated, but few holograms were noticed on the film even though the f_c and f_{cc} agreed closer than ever before. Figures 4, 5 and 6 show f_{cc} and the manual measured f_c. Different holograms were located on the film, but no single proper offset frequency could be found by correlating the holograms on the film with figures 3,4,5 and 6.

All aircraft and pod characteristics were normal.

Flight S-17 June 15, 1962

Flight S-17 was flown immediately after S-16. Again few holograms appeared. Figures 7, 8 and 9 are for the automatic f_c runs. The offset frequency was 4337 cps. Here a bias of about 300 cps between f_c and f_{cc} existed. This did not occur on Run I of S-16 flown the same day, over the same area. The bias is still being investigated. Notice also that some curves in figures 8 and 9 excluding the bias yield rather poor correlation, that is, do not follow each other very closely. Extensive ground tests are planned to isolate the problem.

Other signals were normal on this flight.

Temperatures for Flight 17*

	Beginning of Flight	End of Flight
High Voltage Power Supply Air	128°F	120°F
Nose Compartment Air	75°F	55°F
Duplexer Switch End Surface	90°F	84°F
Pulse Network Surface	78°F	76°F

Ambient Air Temperature = -48C = -54°F

* These also apply to S-16

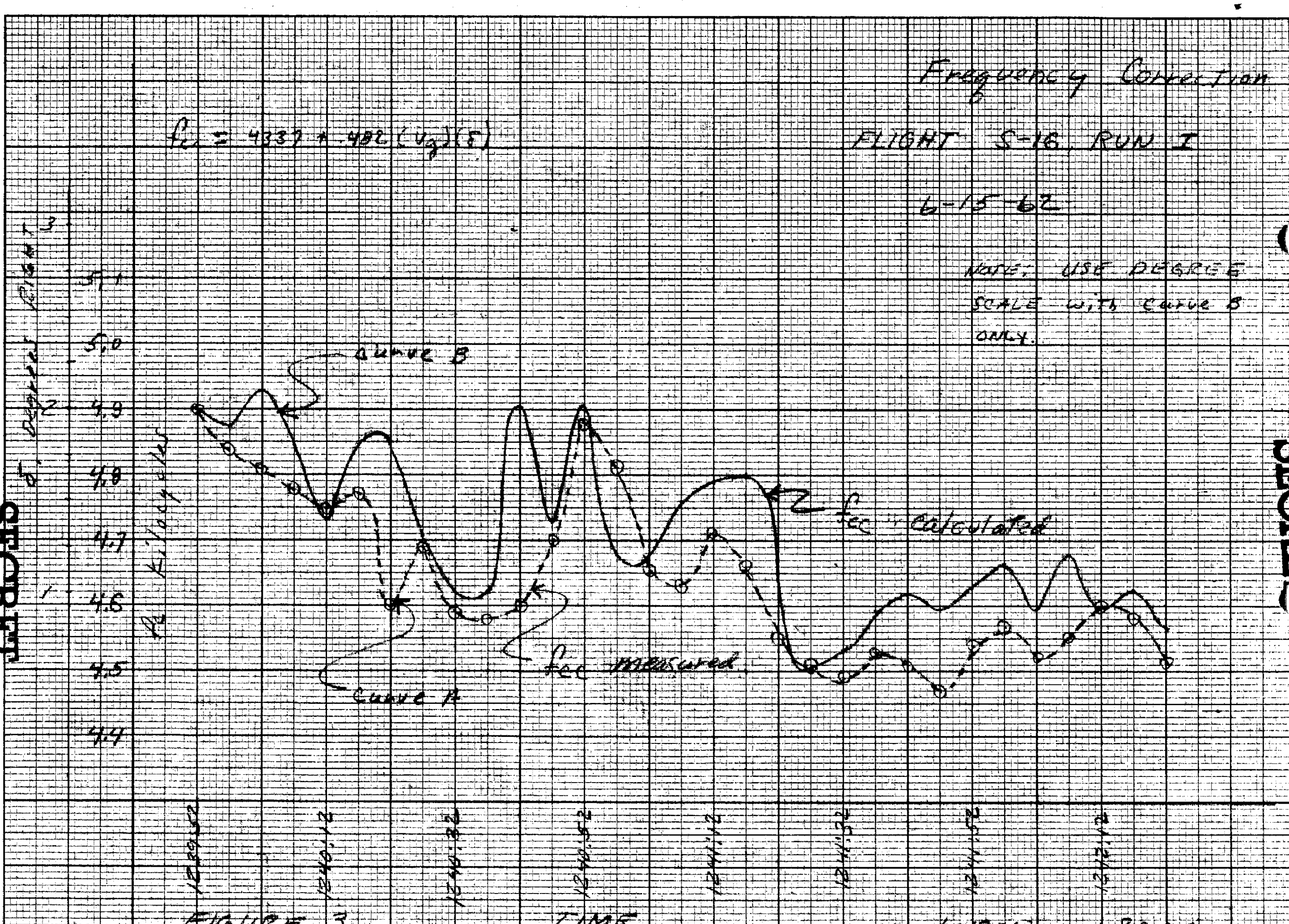


FIGURE 3

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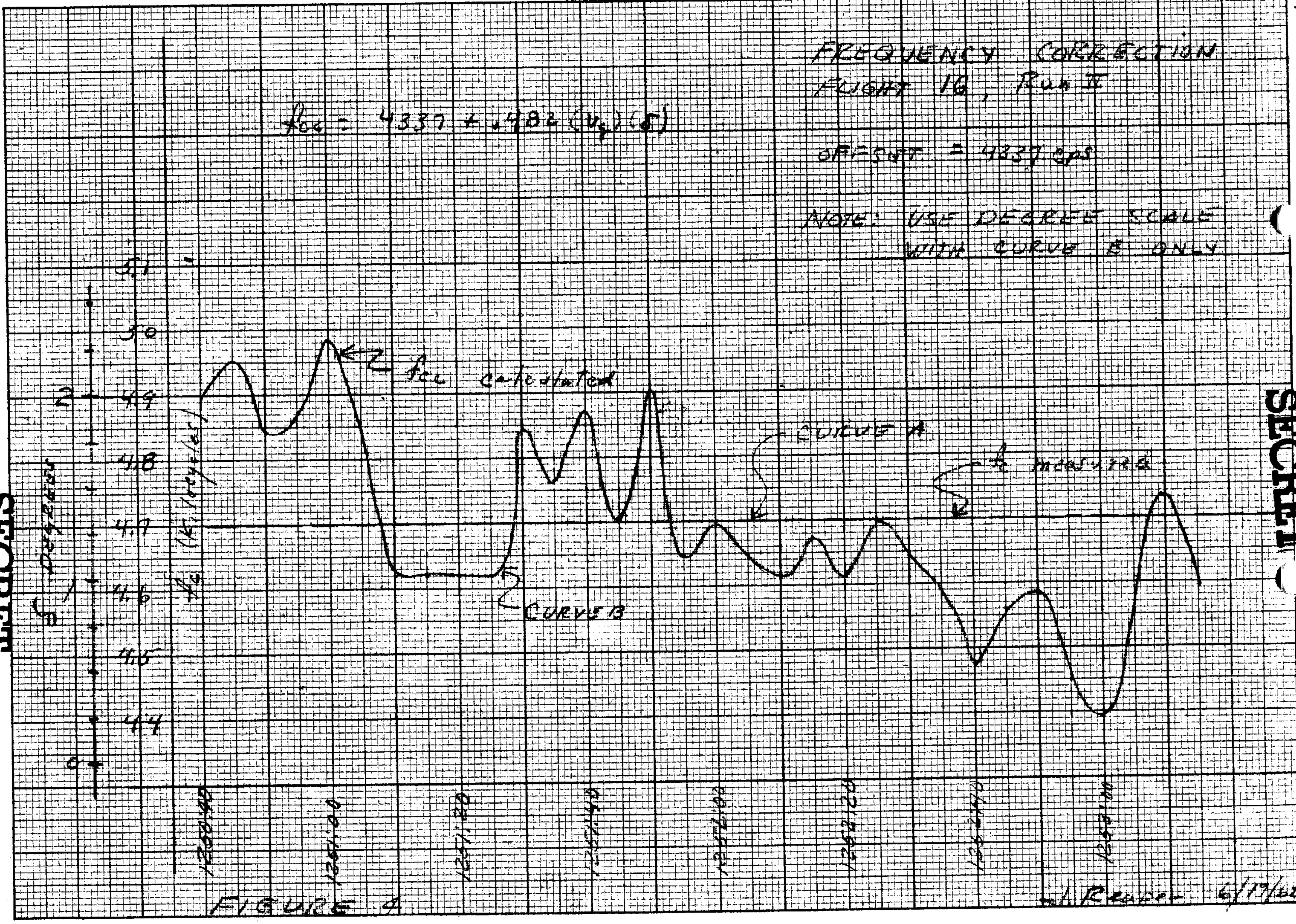

FIGURE 4

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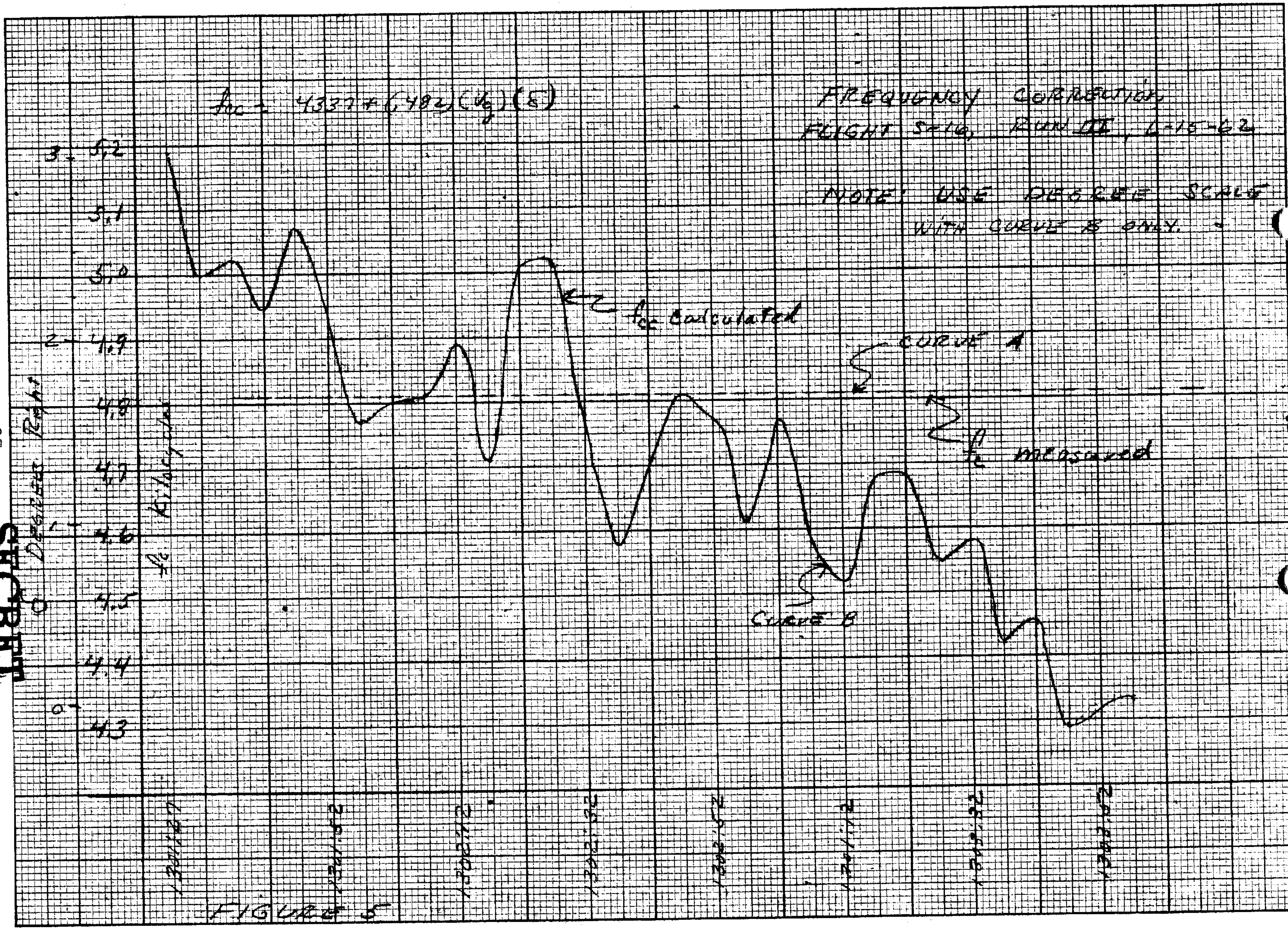
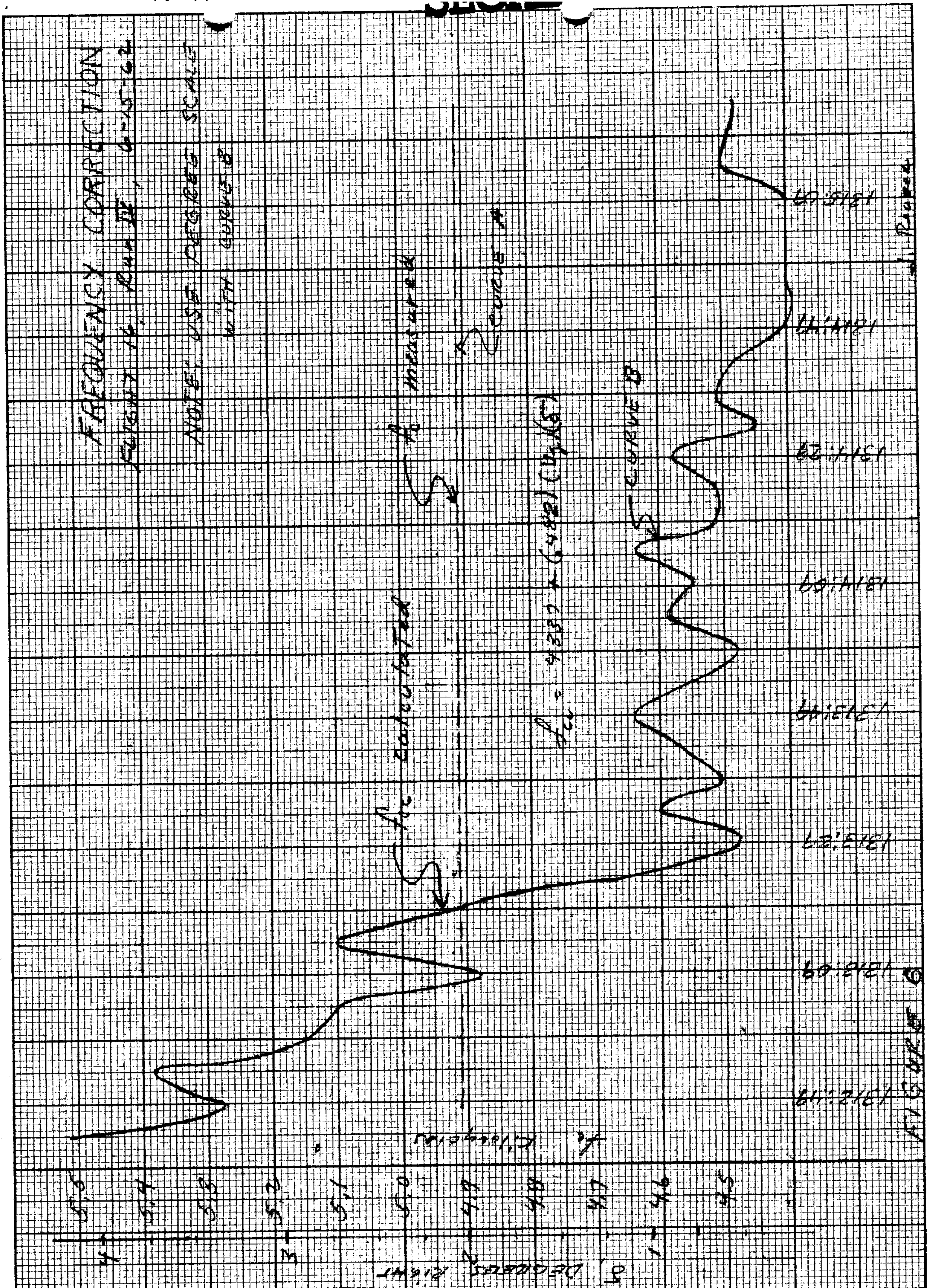

FREQUENCY CORRECTION
FLIGHT S-16, RUN II, 6-15-62
NOTE: USE DEGREE SCALE
WITH CURVE B ONLY.
fcc = 4337 + (482)(Vg)(δ)
fcc Calculated
CURVE A
fc measured
CURVE B
Degrees Right
fc Kilocycles
3
2
1
0
5.2
5.1
5.0
4.9
4.8
4.7
4.6
4.5
4.4
4.3

FIGURE 5


FREQUENCY CORRECTION
FLIGHT 16, Run IV, 6-15-62
NOTE: USE DEGREES SCALE WITH CURVE B
f_o measured
CURVE A
f_c calculated
f_c = 4233 + (4882)(Cn)(G)
CURVE B
1315:09
1314:49
1314:29
1314:09
1313:49
1313:29
1313:09
1312:49
FIGURE 6
f Kilocycles
5.5
5.4
5.3
5.2
5.1
5.0
4.9
4.8
4.7
4.6
4.5
4
3
2
1
.5
Degrees Right

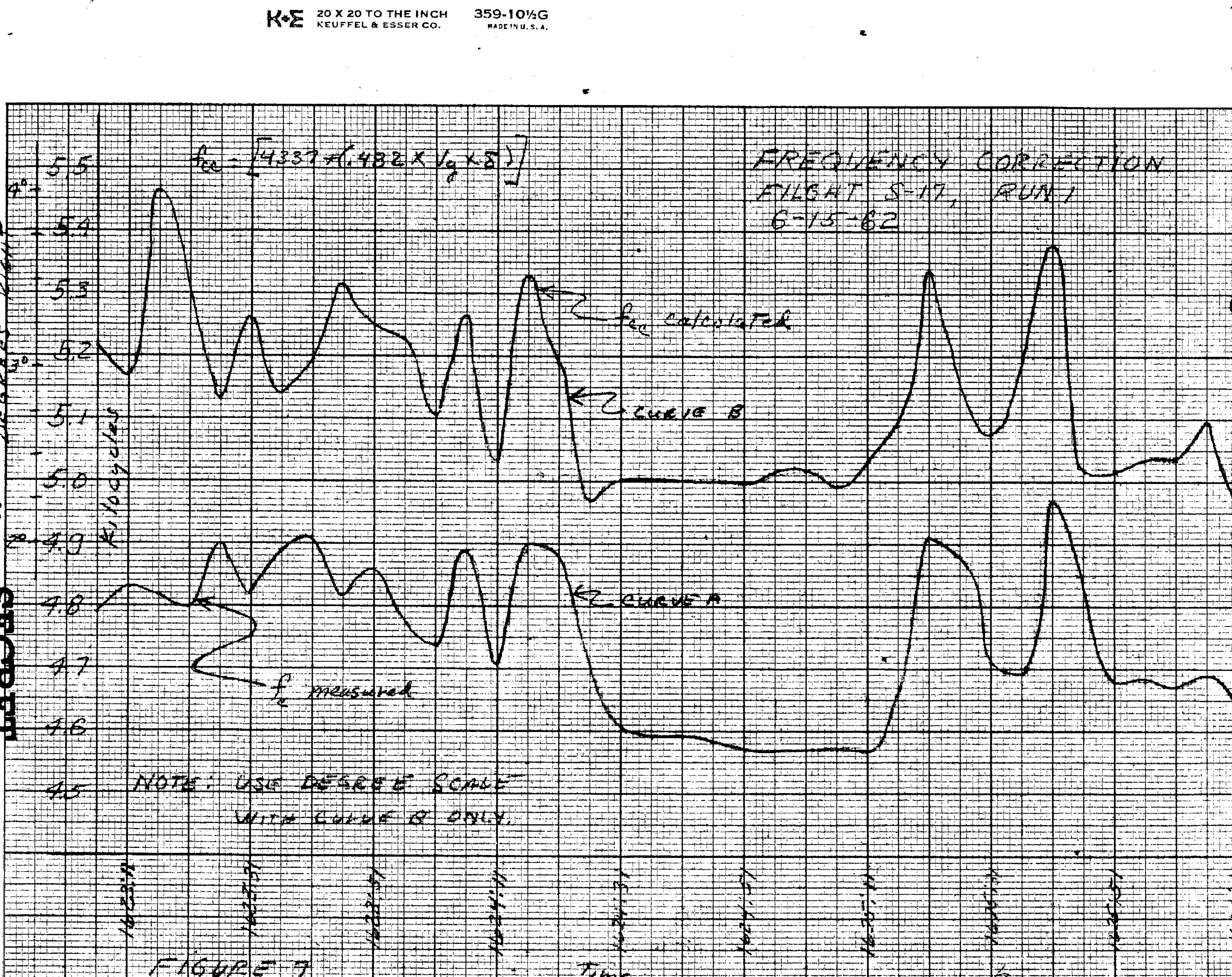
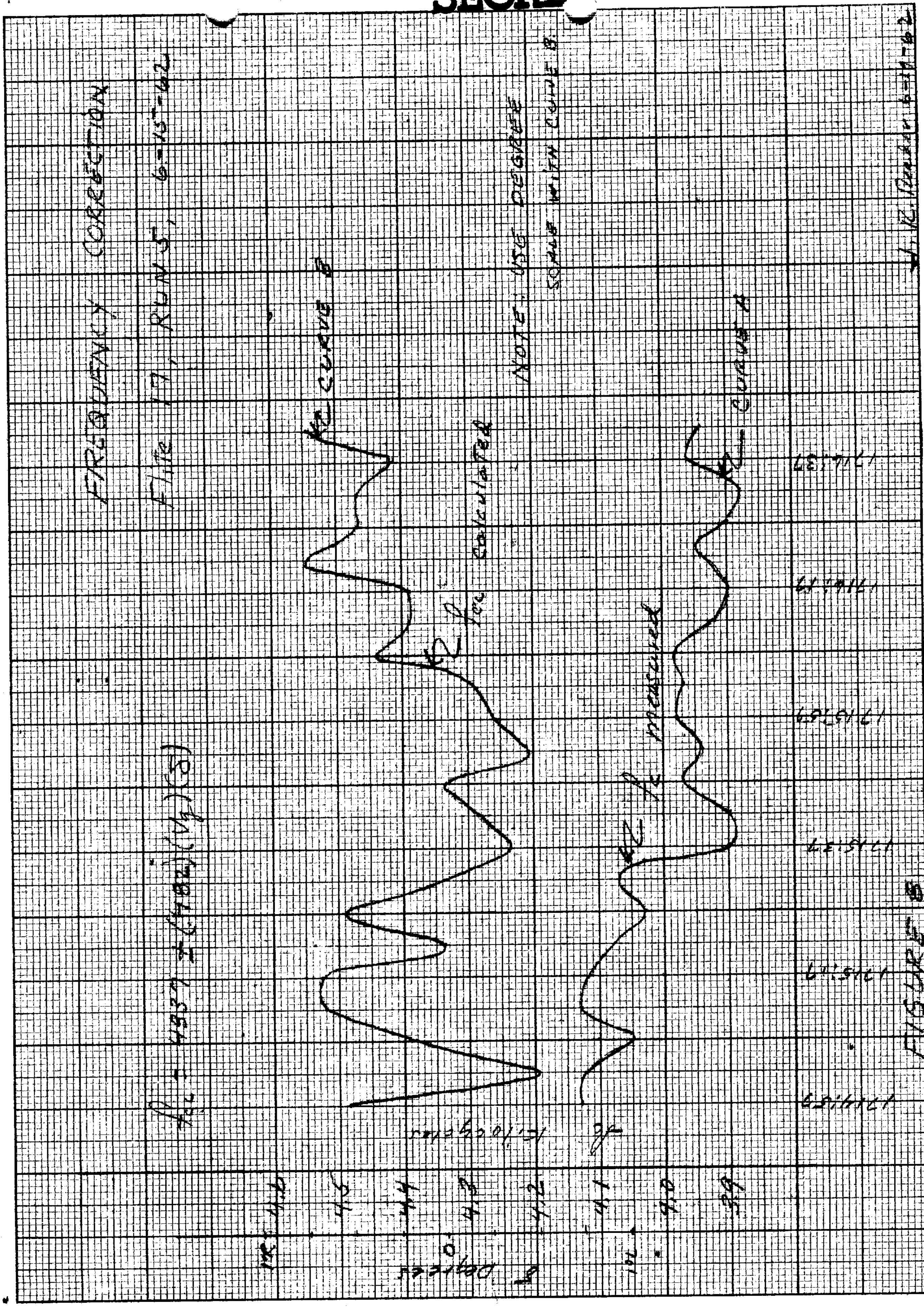
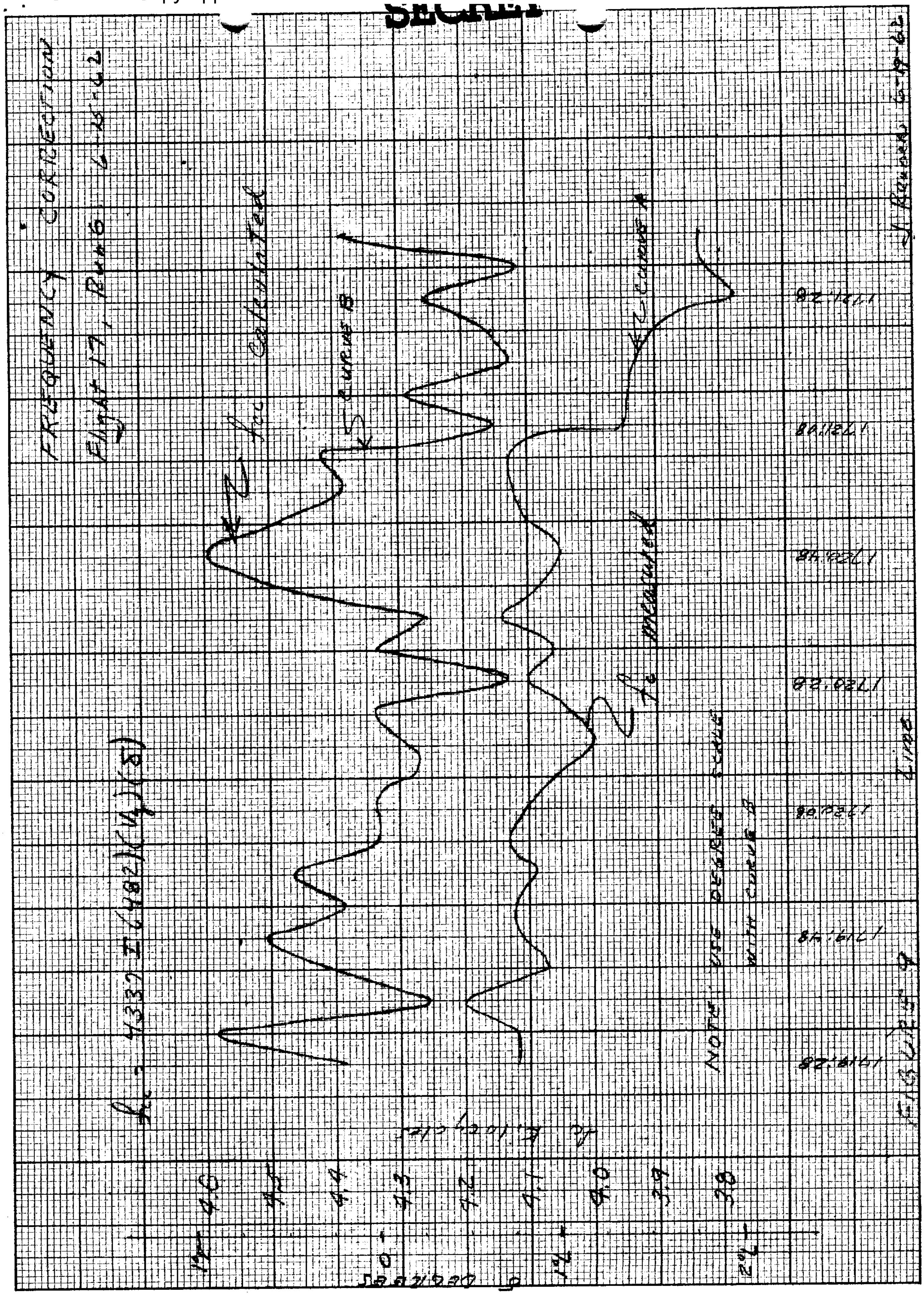

K+E 20 X 20 TO THE INCH KEUFFEL & ESSER CO. 359-10½G MADE IN U.S.A.
$f_{cc} = [4337 + (.482 \times V_g \times \delta)]$
FREQUENCY CORRECTION
FLIGHT S-17, RUN 1
6-15-62
f_{cc} calculated
CURVE B
CURVE A
f_c measured
Kilocycles
Degrees Right
4°
3°
2°
5.5
5.4
5.3
5.2
5.1
5.0
4.9
4.8
4.7
4.6
4.5
NOTE: USE DEGREE SCALE WITH CURVE B ONLY.
Time

FIGURE 7


FREQUENCY CORRECTION
Flite 17, RUN 5, 6-15-62
CURVE B
fcc calculated
NOTE: USE DEGREE
SCALE WITH CURVE B.
fc measured
CURVE A
4.6
4.5
4.4
4.3
4.2
4.1
4.0
3.9
FIGURE 8

SECRET



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APPENDIX

3. DERIVATION OF CALCULATED FREQUENCY CORRECTION, f_{cc}

The equation is composed of three parts: a constant which picks the first spectral line of the returned video when mixed, a term for wind-drift correction based on ground speed and drift angle, and finally a term dependent on the velocity of the plane along the center of the antenna beam. The final equation is:

$$f_{cc} = f_o \pm .482\, V_g \delta + 19.1\, V_B \qquad (1)$$

where f_{cc} = calculated frequency correction

f_o = offset frequency in cycles (measured from the center frequency of the transmitted signal).

V_g = ground speed in knots

δ = drift angle in degrees

V_B = beam velocity in ft./sec.

a. determining f_o

f_o is merely equal to the prf $\pm$ any factors which are constant, like a distorted beam which "squints" ahead or behind the plane.

b. determining the wind-drift term, $0.482\, V_g \delta$

Consider a plane flying straight ahead with an antenna looking at a building or target in front of it. If the antenna transmits a wave described by f_o, λ_o, and traveling iat the speed of light, C, plus the speed of the plane, (v), the target will "see" a wave slightly higher in frequency than that transmitted.

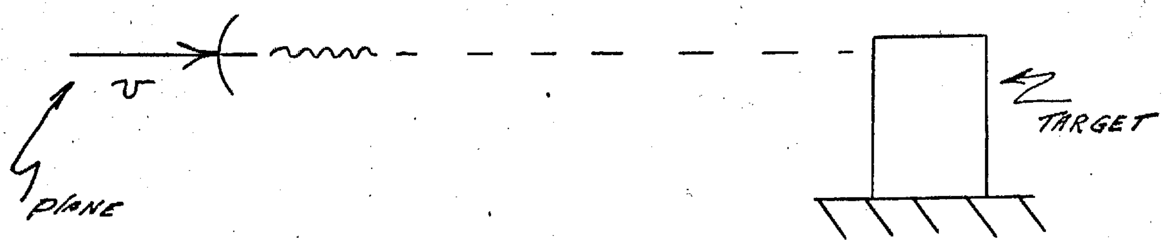


Figure A-1

Then, if V_1, f_1 and λ_1 are parameters of the wave that hit the target, λ_1 is equal to λ_o minus the distance the antenna moves while one cycle is passed out of the antenna.

$$\lambda_1 = \lambda_o - v T_o$$

where T_o is the time required to pass one cycle at a frequency of f_o

then $$T_o = \frac{1}{f_o}$$

and $$\lambda_1 = \lambda_o - \frac{v}{f_o}$$

but $$\lambda_o = \frac{c}{f_o}$$

then $$\lambda_1 = \frac{c - v}{f_o} \qquad (2)$$

Now $$V_1 = c + v$$

Since $$f_1 = \frac{V_1}{\lambda_1}$$

$$f_1 = \frac{c + v}{c - v}(f_o) \qquad (3)$$

Now let f_2, T_2, λ_2, V_2 describe the wave that the receiver sees after is has bounced off the target. Since the plane, (antenna), is still moving at a velocity, $\mathcal{V}$, the return wave has an effective velocity when it hits the antenna of V_2.

$$V_2 = V_1 + \mathcal{V} = C + 2 \qquad (4)$$

then $T_2 = \frac{1}{f_2}$ = time for one cycle to pass into the receiver.

$$T_2 = \frac{\lambda_1}{V_2} \qquad (5)$$

then $\frac{1}{f_2} = \frac{\lambda_1}{V_2}$

$$f_2 = \frac{V_2}{\lambda_1} = \frac{C + 2\mathcal{V}}{C - \mathcal{V}}(f_o) \qquad (6)$$

Now if the difference between f_2 and f_o is called the doppler frequency fd,

then $fd = f_2 - f_o$

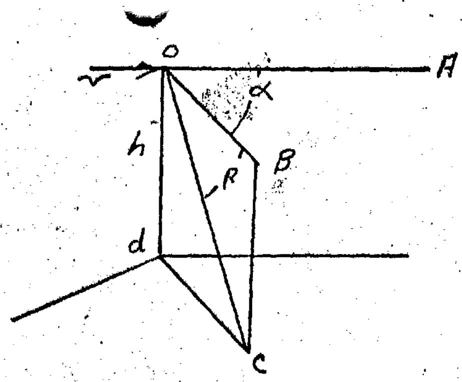
$$fd = \frac{(C + 2\mathcal{V})}{C - \mathcal{V}} f_o - f_o$$

$$fd = \frac{Cf_o}{C - \mathcal{V}} + \frac{2\mathcal{V}f_o}{C - \mathcal{V}} - f_o$$

since C, the speed of light is $>>> \mathcal{V}$ (currently, $\mathcal{V}$ usually does not exceed M2.0).

$$\therefore fd = \frac{2\mathcal{V}f_o}{C} \qquad (7)$$

Now $\mathcal{V}$ is the relative velocity between the antenna and the target. Assume a target which is on the ground and to the right of a plane at a height h.



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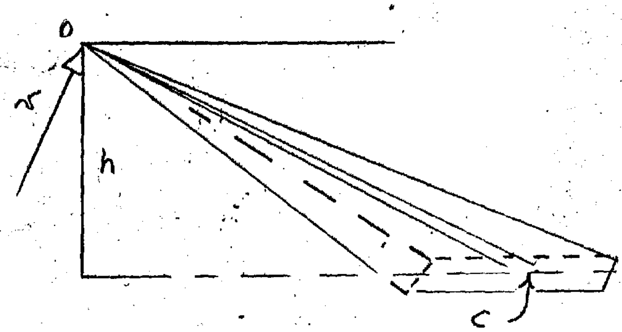
Let the antenna be moving along line OA with a velocity v. Also, let the azimuth angle AOB = α and the depression angle BOC = β. Then the relative velocity between O and C must be found. The relative velocity along line OB is $v_{OB} = v \cos \alpha$ (8)

then $v_{oc} = v_{ob} \cos \beta$ (9)

then $v_{oc} = v \cos \alpha \cos \beta$ (10)

Let OC represent the center of the antenna beam.



Now assuming no roll, β is constant at 31°. However, α varies as drift angle, δ. If a right drift occurs, the plane's nose is to the left of the direction of flight.

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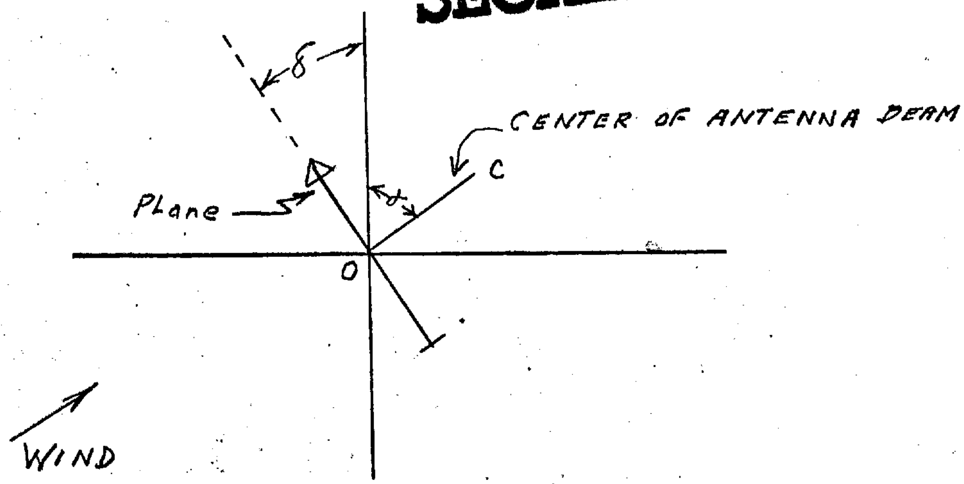

$$\alpha = 90 - \delta$$

then $\quad \cos \alpha = \cos (90 - \delta) = \sin \delta$

then equation 10 can be written,

$$v_{oc} = v \sin \delta \; (\cos 31^\circ) \tag{11}$$

Since δ will usually be small, less than 4°,

$\sin \delta = \delta$ $\quad$ where δ is in radians

converting

$\sin \delta = \dfrac{\delta}{57.3^\circ/\text{rad}}$ $\quad$ where δ is in degrees

Since the doppler navigator in the F-101 computes ground speed along the direction of Flight OA, v in equation 11 can be replaced by V_g, the ground speed. Then equation 11 reads,

$$v_{oc} = V_g \frac{\delta}{57.3} (\cos 31^\circ) \tag{12}$$

Finally, substituting equation 12 into equation 7 the doppler shift due to wind and drift can be written as fwc, wind correction frequency,

$$fwc = \frac{2f_o}{C} V_g \frac{\delta}{57.3} (\cos 31^\circ) \tag{13}$$

V_g and δ are recorded in knots and degrees respectively. For this APQ-93

$$\frac{f_o}{C} = \frac{1}{\lambda} \approx \frac{1}{3.20} \quad \frac{\text{cycles}}{\text{cm}}$$

then

$$fwc = (2)\left(\frac{1}{3.20} \quad \frac{\text{cycles}}{}\right)(V_g)\left(\frac{1 \text{ hr.}}{3600 \text{ sec.}}\right)\left(\frac{185200}{1 \text{ n.mi.}}\right)$$

$$\left(\frac{\delta}{57.3} \quad \frac{(\cos 31°)}{\text{degrees}}\right)$$

$$fwc = \left(\frac{1}{1.6}\right)\left(\frac{1}{36}\right)\left(\frac{1852}{57.3}\right)\left(\frac{\cos 31°}{1}\right)(V_g\delta)\left(\frac{\text{cycles}}{\text{sec}}\right)$$

$$\left(\frac{\text{hour}}{\text{nautical mi.}}\right)\left(\frac{1}{\text{degrees}}\right)$$

$$fwc = .461\ V_g\delta$$

where V_g is in knots, δ is in degrees and fwc in cps.

C. Determining the antenna beam velocity term, ± 19.1 V_B

The antenna beam velocity term compensates for deviations in the frequency range of 2 cps to 0.1 cps. The wind drift term is used for all signals below 0.1 cps. The antenna beam velocity term is based on equation 7 where v is replaced by V_B. V_B is the velocity component of the antenna along the antenna beam and does not include the forward motion of the plane. V_B is derived from an accelerometer and differentiated. Since equation 7 still holds for this case,

$$fd = \frac{2V_BF_O}{C}$$

where fd is the doppler frequency caused by V_B,

$$fd = 2V_B \left(\frac{f_o}{C}\right) = \frac{2V_B}{\lambda_o} = \frac{2V_B}{3.2\ \text{cycle}} \left(\frac{30.48}{ft}\right) = 19.05\ V_B \left(\frac{\text{cycles}}{ft}\right)$$

$$fd = 19.05\ V_B$$

where fd is in cps and V_B in feet/second

The entire equation is then

$$f_{ce} = f_o \pm .482\ V_g\ \delta \quad \pm 19.1\ V_B$$

Since V_g is usually 585 or 830 and a 1° - 3° drift angle is not uncommon, the second term contributes much more to the equation than ± 19.1 V_B. Therefore, since V_B is usually less than 2 feet/second, it has been at times neglected in the calculation of f_{ce}. (For the past few flights the accelerometer has been disconnected from the system also). It must be remembered that a constant β (depression angle) was assumed of 31° with no roll angle. Actually β varies from 21 to 41°. Considering the 1/4° of error in δ that exists from the doppler navigator, and measuring errors, f_{ce} should agree within 100 - 150 cps.

APPENDIX

4. C.E.C. OSCILLOGRAPH RECORDED SIGNALS

a. Normal Acceleration

The acceleration of the APQ-93 pitch stabilized pod exhibits both sinusoidal and non-sinusoidal characteristics. The non-sinusoidal portions yield peak accelerations of about ± .07g which rise and decay in about 10 seconds at ground speeds of 585 knots. (For 830 knots the peaks are greater (-.18 to +.10) but rise and decay times usually less). The sinusoidal portions have two frequencies, one at 0.8 cps, with a peak-to-peak amplitude of .04g to .14g and occurs about 50 percent of the time. The other at 8-10 cps, the natural lateral frequency of the pod occurs 30 percent of the time and has peak-to-peak values of .04g to .06g. Both of these sinusoids occur in bursts of 9 seconds and 0.8 seconds for the 0.8 cps and 8-10 cps signals respectively. There is no data for characteristics of the pod in other than light or moderate turbulence.

b. Lateral Acceleration

The lateral acceleration of the pod is essentially an 8-10 cps signal, the pod's natural lateral frequency. The amplitude of this signal varies from .05 to .1g for light turbulence at 585 knots and up to .16g peak-to-peak for moderate turbulence. No non-sinusoidal characteristics could be located.

c. Vibration

At speeds of 585 knots, (M.9), the predominate frequencies range from 80-100 cps with amplitudes from 1.0G to 1.5G and at 830 knots from 120-150 cps with .6 to 1.2G peak-to-peak amplitude.

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d. Roll

The F-101-B exhibits a roll with a continual oscillation of .4 to .7 cps of .7° to 1.0° peak-to-peak amplitude. No significant changes exist when the aircraft is flown with or without the MB-5 autopilot. Little Change exists between M.9 and M1.5 speeds.

e. Pitch

The F-101-B has a normal nose-high attitude of 1.5° to 3.0° depending on speed and fuel consumption. For 585 knots, 2.8° is the normal value. An oscillation of .8 cps occurs in bursts of about 9 seconds with a peak-to-peak amplitude of .3°. These sections of oscillations occur about 50 percent of the time.

f. Autopilot Heading Error

This signal seldom varies more than ±1° which is within the limits of the autopilot. No predominate oscillations exist.

g. Track Error

This signal is the difference between the desired heading of the plane and the actual heading of the ground track. It is derived from the doppler navigator - ground track computer installation. (APN-102 and ASN-25). It is usually less than ±2° but is dependent upon the pilot.

h. Distance Off Track

This signal is also derived from the ASN-25 and is the distance from the actual ground track to the desired ground track measured perpendicular to the desired track. Like track error the limits are dependent upon the pilot. Experience has shown that on a good run the signal doesn't vary more than ±.2 n.mi.

i. Pod Error

The pod error signal definitely shows the 8-10 cps oscillation occurring at the same times as this oscillation on the normal acceleration signal. The pod servo cannot follow an 8 to 10 cps oscillation but the average of the signal is α.

j. Ground Speed

This signal is a function of the pilot only and is best described by Figure III.

k. Drift Angle

Drift angle shows a .5 to 1 cps oscillation of small amplitude of ±.25° to ±.5°. This oscillation exists continually. Figure IV shows drift angle (δ) averaged over 10 second periods.

l. Frequency Correction Command

This signal varies slowly because of the filtered inputs and follows δ, drift angle closely as in equation 1 and Figure I.

m. Antenna Beam Velocity

The velocity of the antenna relative to the target, excluding that due to the planes' forward motion usually is a slowly drifting signal of very low amplitude. The signal never exceeds ±5 feet/second which has little effect on f_c of equation 1.

n. Temperatures

Below are listed the temperatures recorded at 17,000 feet:*

Nose Compartment Air Temperature	41°F
Duplexer Driver Surface Temperature	94°F

Duplexer Surface Temperature	100°F
Duplexer Surface Temperature (Switch End)	83°F
High Voltage Power Supply Air Temperature	120°F
Pulse Network Surface Temperature	100°F

*Ambient Temperature = 18°C